Nuclear Transmutation in Electrolysis

Nuclear Transmutation in Electrolysis with Porous Ni Cathode and $H_2O + K_2CO_3$ Electrolyte

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Abstract

The experimental data of the observation of the nuclear transmutation into ^{40}K and ^{64}Cu were analyzed using the TNCF model. The result gives a consistent explanation of the experimental data with a density of the trapped neutrons $n_n = 1.4 \times 10^9$ cm^{-3} which is comparable to the value obtained before for similar samples.

1. Introduction

The nuclear transmutation (NT) in solids used in cold fusion (CF) experiments has been widely investigated in the last several years. At first, the phenomenon was taken with reservation, even by the people working in the field of the cold fusion. However, the more the CF research proceed, the more evidence of transmutation piled up.

We have applied several data[1-5] of NT in relation with the analyses of CF experiments using the TNCF model[6-9] which gives a consistent explanation of both phenomena.

In this paper we will take up an experiment[10] where the transmutation was observed of several nuclei and a production of positrons in a porous Ni cathode with electrolytes $H_2O + K_2CO_3$.

2. Experimental Results

In a series of experiments with Ni cathode in H_2O (and D_2O) solution of electrolytes K_2CO_3 (and Li_2CO_3, Na_2CO_3, Rb_2SO_4, Cs_2SO_4), Notoya et al.[10-12] observed NT and positron generation in the system by observing the gamma ray spectrum. In addition to the production of ^{40}K, ^{56}Co, ^{64}Cu and ^{65}Zn, they detected a 0.511 MeV line due to the positron annihilation.

In the case of a porous Ni cathode with a dimension of 1.0 x 0.5 x 0.1 cm^3 and a density 58% of Ni metal and a electrolytic solution of 0.5M K_2CO_3 + H_2O (20 to 30 m*l* as a whole), they observed an increase of ^{40}K by 100% after 24 hours of electrolysis and the annihilation gamma ray at 0.511 MeV. The increase by 100% in the solution corresponds to a generation of ^{40}K by

3.0×10^{16} nuclei.

The intensity of the 0.511 MeV gamma ray corresponded to 2.53×10^{-2} Bq of ^{64}Cu, by the authors' evaluation, after electrolysis of 50 hours. This value corresponds to 8.8×10^{3} nuclei of ^{64}Cu which was absent prior to the experiment.

The surface area of Ni particle in the above described cathode was determined by the new impedance method as 10^3 cm^2, 10^3 times the surface area of the cathode plate[13].

Whole data obtained by the authors are summarized as follows[10]; (a) Gamma peaks due to ^{22}Na and ^{24}Na, ^{40}K, ^{89}Rb and ^{92}Sr, or ^{134}Cs and ^{135}Xe during each electrolysis of Na^+, K^+, Rb^+ or Cs^+ solution, respectively. (b) Gamma peaks due to ^{56}Co, ^{64}Cu and ^{65}Zn were shown in the cases of all electrolytes including even Li^+ solution. (c) A gamma peak due to the positron annihilation was also observed in every solutions at 511 keV. (d) Liquid scintillation spectra showed the increment of tritium produced by electrolysis in all light and heavy water solutions except with Rb^+.

We will confine our investigation only to ^{40}K, ^{64}Cu and tritium events in this paper though there are such a lot of data listed above which are possible targets of the analysis on the same line.

3. Analysis of Experimental Data

To analyze the interesting experimental data[10] introduced above, we use the TNCF model[6-9], in which an existance was assumed of stable trapped neutrons in solids (porous nickel cathode in this case). The trapped neutrons are supposed to be stable except when strong perturbation acts on them. We will use a symbol n_n to denote the density of the neutron in the sample.

Relevant reactions could be written down as follows.

The trapped neutron fuse with a ^{39}K nucleus with the natural abundance 93% in the surface layer of potassium metal with an assumed thickness 1 μm:

$$n + {}^{39}\mathrm{K} = {}^{40}\mathrm{K}. \quad (1)$$

The fusion cross section of this reaction for the thermal neutron is 2.2 barns (2.2×10^{-24} cm^2).

The nucleus ^{40}K generated in this reaction disintegrates emitting electron with a decay constant 1.28×10^9 y and also fuses with a neutron to form a stable nucleus ^{41}K with a cross section 70 barns:

$$n + {}^{40}\mathrm{K} = {}^{41}\mathrm{K}. \quad (2)$$

On the other hand, possible reactions to generate ^{64}Cu are assumed to occur in the cathode as follows:

$$^{62}\mathrm{Ni} + n = {}^{63}\mathrm{Ni} \rightarrow {}^{63}\mathrm{Cu} + e^- + \nu_e, \quad (3)$$
$$^{63}\mathrm{Cu} + n = {}^{64}\mathrm{Cu} \rightarrow {}^{64}\mathrm{Ni} + e^+ + n_e, \quad (4)$$

The natural abundance of ^{62}Ni is 3.66%. Fusion cross sections of the above two reactions are 15 and 4.5 barns, respectively. Decay constants of ^{63}Ni and ^{64}Cu are 92 y (~ 10^9 s) and 12.7 h (4.6×10^4 s), respectively. The decay of ^{64}Cu includes other two modes of electron emission and electron capture and the branching ratio of the above mode of positron emission in the relation (4) is 19%.

(1) ^{40}K generation.

The number $N_{M'}$ of the transmuted nucleus M' (^{40}K) in a time τ is calculated by a following equation in relation with the density of the trapped neu-

tron n_n:

$$N_{M'} = 0.35\, n_n v_n r_M V \sigma_{nM} \tau \qquad (5)$$

where v_n is the thermal velocity of the neutron, ρ_M is the number density of the transmuting nucleus M (^{39}K), V is the volume of a region (surface layer) where the fusion reaction occurs and σ_{nM} is the fusion cross section of the thermal neutron and the nucleus M. As the region where occurs the transmutation into ^{40}K, we take a surface layer of the potassium metal on the Ni cathode surface (with the area 10^3 cm^2) the thickness of the layer is assumed as 1 μm rather arbitrarily. The relation (5) has been applied to surface layers where the trapped neutrons are unstable and are easy to fuse with foreign nuclei. In the volume, however, the neutrons are more stable and we have to add another factor to specify the situation as shown below (in relation (6)).

Using numerical data given above and $\rho_{K39} = 1.3 \times 10^{22}$ cm–3 and $v_n = 2.7 \times 10^5$ cm/s (300°K), we obtain a following value for the density of the trapped neutron from the experimental data of ^{40}K generation of 3.0×10^{16} nuclei in 24 hours: $n_n = 1.4 \times 10^9$ cm^{-3}.

This value is very reasonable one compared with other data obtained hitherto in the analyses of experimental data[2,4,14,15].

(2) ^{64}Cu generation.

The amount of ^{64}Cu of 2.5×10^{-2} Bq evaluated by the authors[10] corresponds to the number N_{Cu64} of 8.8 x 103 nuclei in the cathode.

To calculate a number of the transmuted nuclei in volume, we use a following relation instead of the relation (5), which has been used for the fusion reactions in the surface layer where the perturbation of the neutrons is large:

$$N_{Mt} = 0.35 n_n v_n x r_M V s_{nM} t \qquad (6)$$

In this equation, ξ expresses a constant due to stability of the neutron in volume compared with in the surface layer.

Using the relation (6) with the value 10^9 cm^{-3} for n_n determined from the number of the nuclei ^{40}K, we obtain a number Cu63 of the nuclei ^{63}Cu in the cathode which fuse with the trapped neutron by the reaction (4) to give ^{64}Cu of 8.8×10^3 nuclei in 50 hours:

$$N_{Cu63} = 8.3 \times 10^7 \xi^{-1}.$$

This number of the isotope ^{63}Cu in the sample generated by the reaction (3) (assuming absence of ^{63}Cu in the initial cathode) determine the number of the isotope ^{63}Ni by the relation (6). The time τ_{Ni} in which the ^{62}Ni fuses with the trapped neutron to generate ^{63}Ni which decays into ^{63}Cu of the above number is evaluated as follows:

$$\tau_{Ni} = \frac{4.5 \times 10^{-4}}{(1 - 2^{-T/\tau_{Ni}})2} \xi^{-} s,$$

where T is the time while ^{63}Ni decays into ^{63}Cu with the half-life time of τ_{Ni}.

In this calculation, the same factor ξ in the fusion of the trapped neutron with the nucleus ^{62}Ni in the volume of the cathode was used.

From this relation, we can evaluate the efficiency coefficient ξ for the fusion reaction in the volume using a time about one day (8.6×10^4 s). Assuming $\tau_{Ni} = 8.6 \times 10^4$ s, we obtain the efficiency coefficient ξ of the volume nuclei ^{62}Ni and ^{63}Cu (assuming the same factor for the both nuclei) as 1.4×10^{-2},

i.e. foreign nuclei in the volume are less effective to fuse with the trapped neutrons by a factor of 1.4×10^{-2} (or they are effective only 1.4% of those in the surface layer).

(3) Tritium generation.

The increase of tritium could be expected by the following reactions:

$$n + p = d + \gamma, \\ n + d = t + \gamma.$$

The fusion cross sections of these reactions are 0.35 barns and 0.55×10^{-3} barns, respectively.

We can conclude from our model that the increase of tritium in D_2O case is more than in H_2O by a factor of 10^3 in the initial stage of the experiment if there are no other reactions expected to generate tritium than the reaction (8). The increase of tritium in H_2O case will be intensified in the progress of the experiment due to the increase of deuterium by the reaction (7).

4. Discussion

The excess heat, nuclear products and the transmuted nuclei could be considered as indicators of phenomena occurring in materials with some characteristics which are not fully identified yet, though their facets have been recognized. The facets of the characteristic of the cold fusion phenomenon are the inclusion of hydrogen isotopes in some transition metals, precipitation of some alkali metals on the surface of the transition metals, and so forth.

The poor reproducibility, a notorious characteristic of the cold fusion phenomenon, has been largely improved qualitatively, especially by the use of materials with small dimension such as Patterson's beads, Italian thin wires, and Pd black.

The porous nickel used by Notoya et al. belongs in this category of materials with small dimension. The sample seems to be a sintered Ni powder with a small diameter. They have observed NT accompanied with the excess heat for several years in those cathodes with high qualitative reproducibility[11,12].

What these experimental facts show us is some unknown entity in the material or some unknown behavior of known elements in it. One of the present authors (H.K.) has proposed a concept "missing factor" to express such a situation. To solve the difficulty involved in the cold fusion phenomenon, it will be necessary to find a missing factor which is not yet recognized, but which plays a key role in the realization of the phenomenon.

Trapped thermal neutrons is the missing factor in the TNCF model. The density of the trapped neutron denoted by n_n is an adjustable parameter determined by experimental data. When there are several physical quantities determined by experiments and related with n_n, consistency of the values n_n determined by different quantities testifies validity of the model.

The TNCF model has shown consistent explanations of the experimental data obtained in various materials[14,15]. In addition to these results, the present analysis showed another consistent explanation of two data of the increase of ^{40}K and the generation of ^{64}Cu in the porous Ni cathode.

The use of fine Ni powder sample reminds us the experiment of Reifenschweiler[16] where a fine particle

of $TiT_{0.0035}$ with a diameter 15 nm showed a temperature consistent explanation was given with a density of the trapped neutron of 1.1×10^9. This value is very close to the value obtained above in the porous Ni cathode of 1.0×10^9 cm^{-3}. This coincidence should be not accidental and shows ability of the Ni fine powder to trap the thermal neutrons.

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